ELECTRICAL AND ELECTRONIC MATERIALS

Code: EEC/EPM1160

Lecture: 3 **Tutorial: 1** **Total: 4**

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This course aims at providing the basic knowledge in order to:

- Know the principles of dielectric constant, polarization and electric dipole moment (DM)
- Recognize the characteristics of piezoelectricity and Ferro electricity
- Realize the dependence of electronic polarizability and Ionic polarization on the frequency
- Know the meaning of magnetic polarization, diamagnetism, paramagnetism and ferromagnetism
- Deal with dielectric losses and magnetic (DM)
- Realize the principles of superconductivity and josphson junction

Intended Learning Outcomes (ILOs)

Knowledge and Understanding

a1- Identify the dielectric constant, the electric dipole moment and the polarization

a2- Mention the conditions and applications of piezoelectricity and Ferro electricity

a3- Identify the frequency dependence of electronic polarizability and ionic polarization

a4- Outline the types of magnetic materials

a5- State the relations used to calculate the Dielectric losses

a6- Determine the types and applications of superconductivity and josphson junction.

Intended Learning Outcomes (ILOs)

Intellectual Skills

- b1- Differentiate between electric and magnetic dipole moments
- b2- Recognize the conditions of occurring the piezoelectricity and Ferro electricity
- b3- Predict the frequency dependence of electronic polarizability and ionic polarization
- b4- Compare the characteristics of different types of magnetic materials
- b5- Develop the relations used to calculate the Dielectric losses
- b6- Distinguish the types of superconductors

Intended Learning Outcomes (ILOs)

Professional and Practical Skills

c1- Predict the relation between the dielectric constant and frequency

c2- Calculate the polarizability and dipole moment for different types of polarization

c3- Apply the suitable formulas to calculate the Dielectric losses

c4- Solve the relations related to the magnetic circuits

c5- Distinguish the types of superconductors

Intended Learning Outcomes (ILOs)

General and Transferable Skills

d1- Collect suitable data about the topic of electric materials

d2- Cooperate to process the collected data

d3- Work within specific time

Weighting of Assessments (100)

Mid-Term Examination	10 %
Final-term Examination	70 %
Oral Examination.	0.0 %
Practical Examination	0.0 %
Semester Work	20 %
Other types of assessment	0.0 %
Total	100%

References

- Dr Salah Khames and Dr. Ahmed Refaat, “Electric and electronic materials”
- Jones I.P., “Materials science for electrical and electronic engineers”, Oxford University Press, Oxford, New York, 2001
- Kasap S.O., “Principles of electrical engineering materials and devices”, mcgraw-hill, boston, 2000
- Tareev, Boris Mikhailovich, “Physics of dielectric materials”, Mir, Moscow, 1975
- Von Hippel, Arthur R, “Dielectric materials and applications", John Wiley & Sonns, New York, 1958

Electrical materials

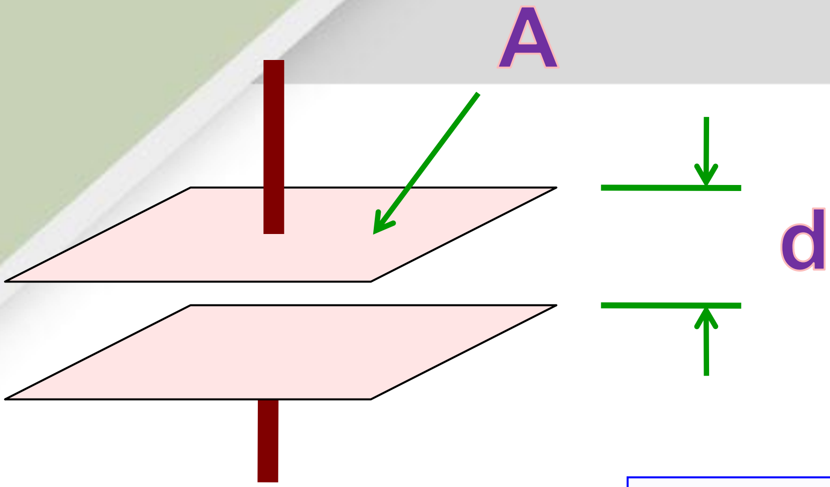
Comprise a wide-range of industrial materials utilized to manufacture electrical machines, instruments, apparatus and other electrical elements and equipment

- Insulators → No enough free electrons
- Conductors → free electrons and loosely bound outer electrons
- Semiconductors

Electrical materials

	Resistivity (ohm . m)
Glass	10^{12}
Mica	9×10^{13}
Quartz	5×10^{16}
Copper	1.7×10^{-8}

Static Dielectric Constant



$$C = \varepsilon \frac{A}{d}$$

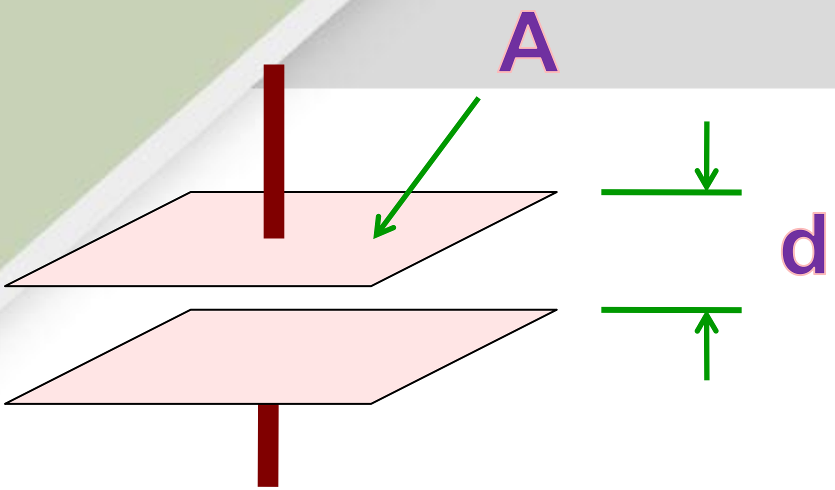
$$\varepsilon = \varepsilon_o \cdot \varepsilon_r$$

ε: the permittivity (farads per meter)

ε_o: permittivity of free space (8.85×10^{-12} F/m)

ε_r: relative permittivity (dielectric constant)

Static Dielectric Constant



$$C = \varepsilon_0\, \varepsilon_r\, \frac{A}{d}$$

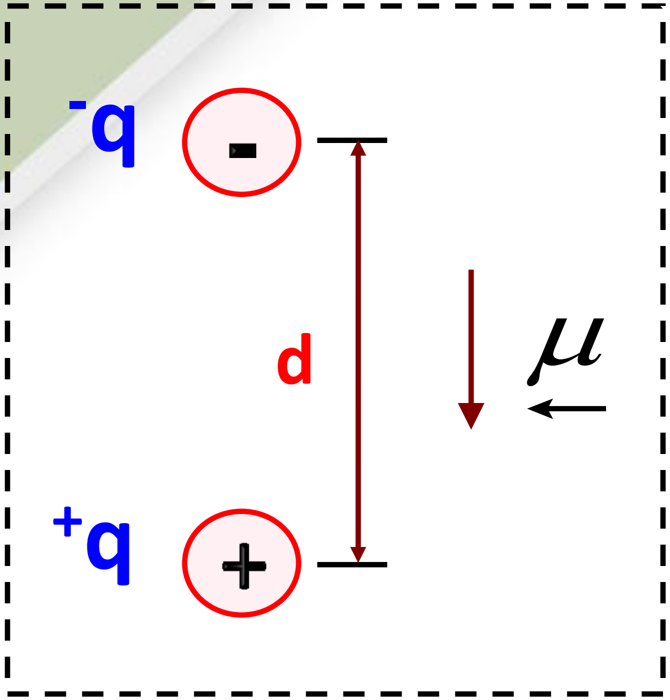
The dielectric constant of a substance (ε_r) is the ratio of the capacity of a condenser with that substance used as the dielectric medium to the capacity of the same condenser with vacuum used as the dielectric medium

Static Dielectric Constant

The value of ε_r in a **steady electric** field is known as the static relative permittivity

The static dielectric constant is the dielectric constant at frequencies low enough that the equilibrium is maintained with the electric field variations

Dipole Moment



$$\vec{\mu} = q\vec{d}$$

The electric dipole moment for a pair of opposite charges having a magnitude of **q** and separated by a distance **d** between them is defined as the magnitude of the charge times the distance between them and <u>the defined direction is toward the positive charge</u>

Dipole Moment

The net charge within the region that contains the positive and negative charges is zero

If the centres of the two charges are coincident, the dipole moment will be zero

Polarization

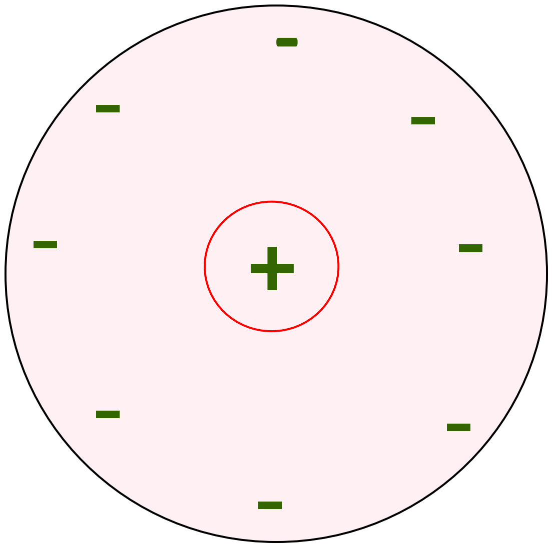
The dielectric constant represents an interesting material parameter *only* when the material is subjected to an electrical field. The electrical field can cause two effects:

- It tries to align electric dipoles that are already present in the material even without a field
- It induces new electrical dipoles in the material and acts to align them in the field direction

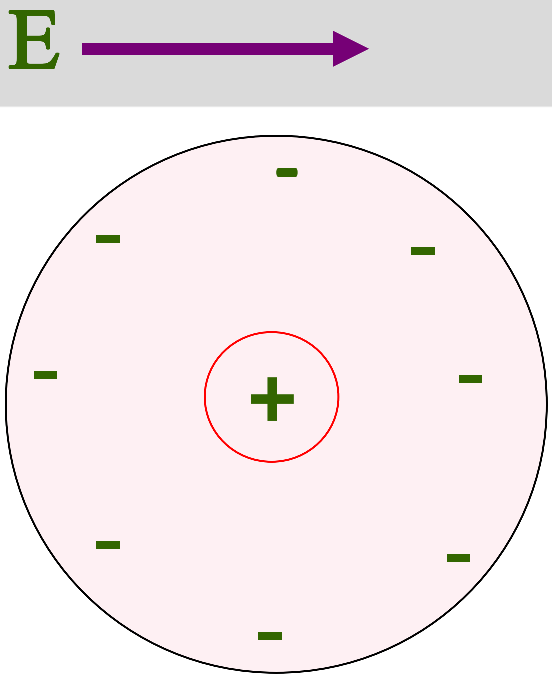
Polarization

The overall influence of an electrical field on a dielectric material is defined as the polarization of the material

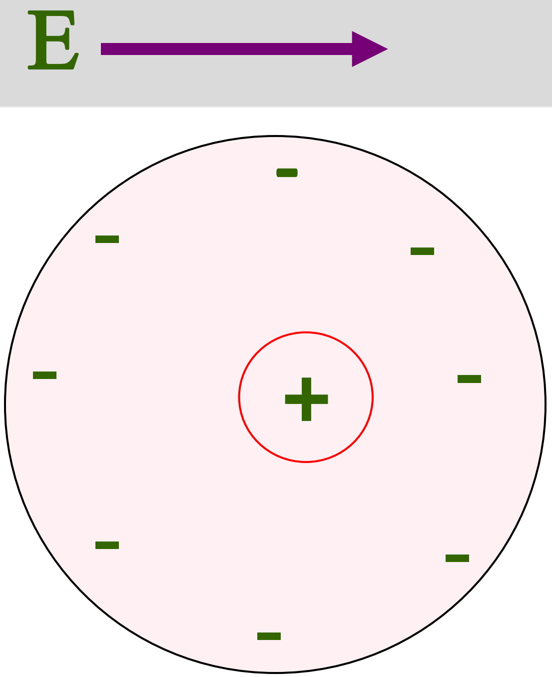
Polarization



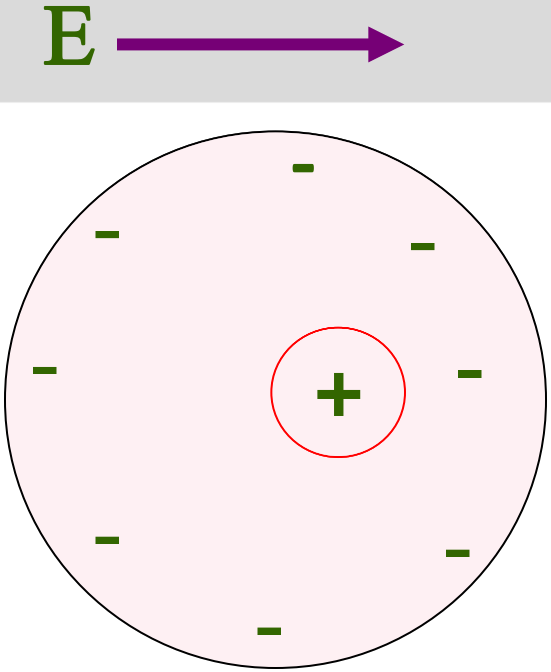
Polarization



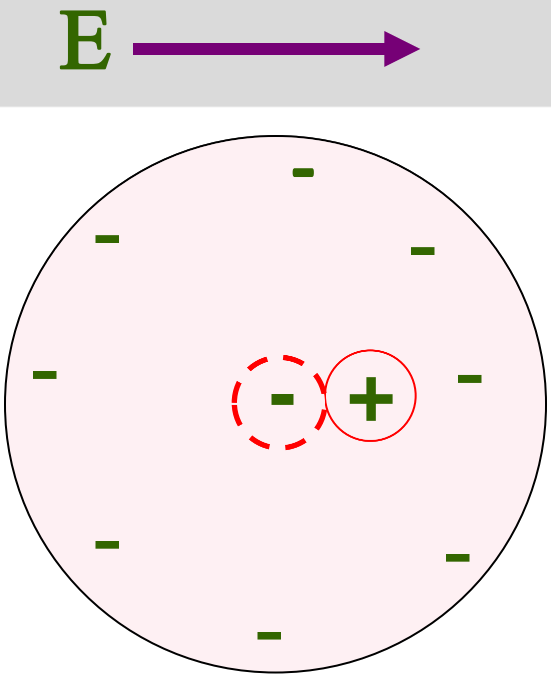
Polarization



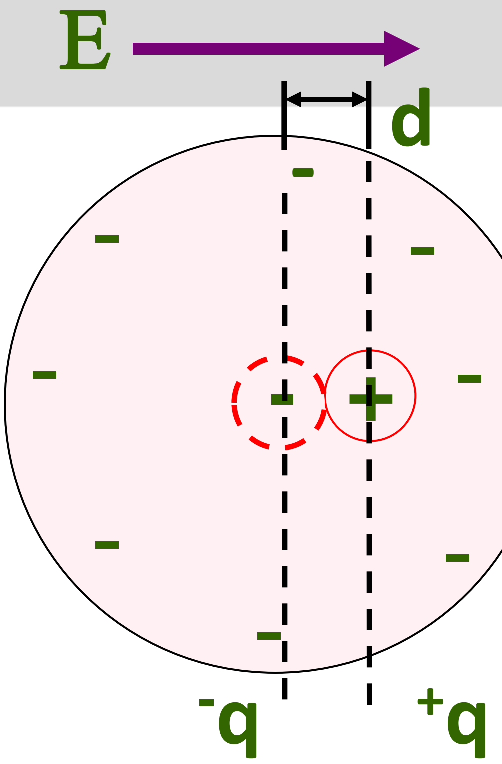
Polarization



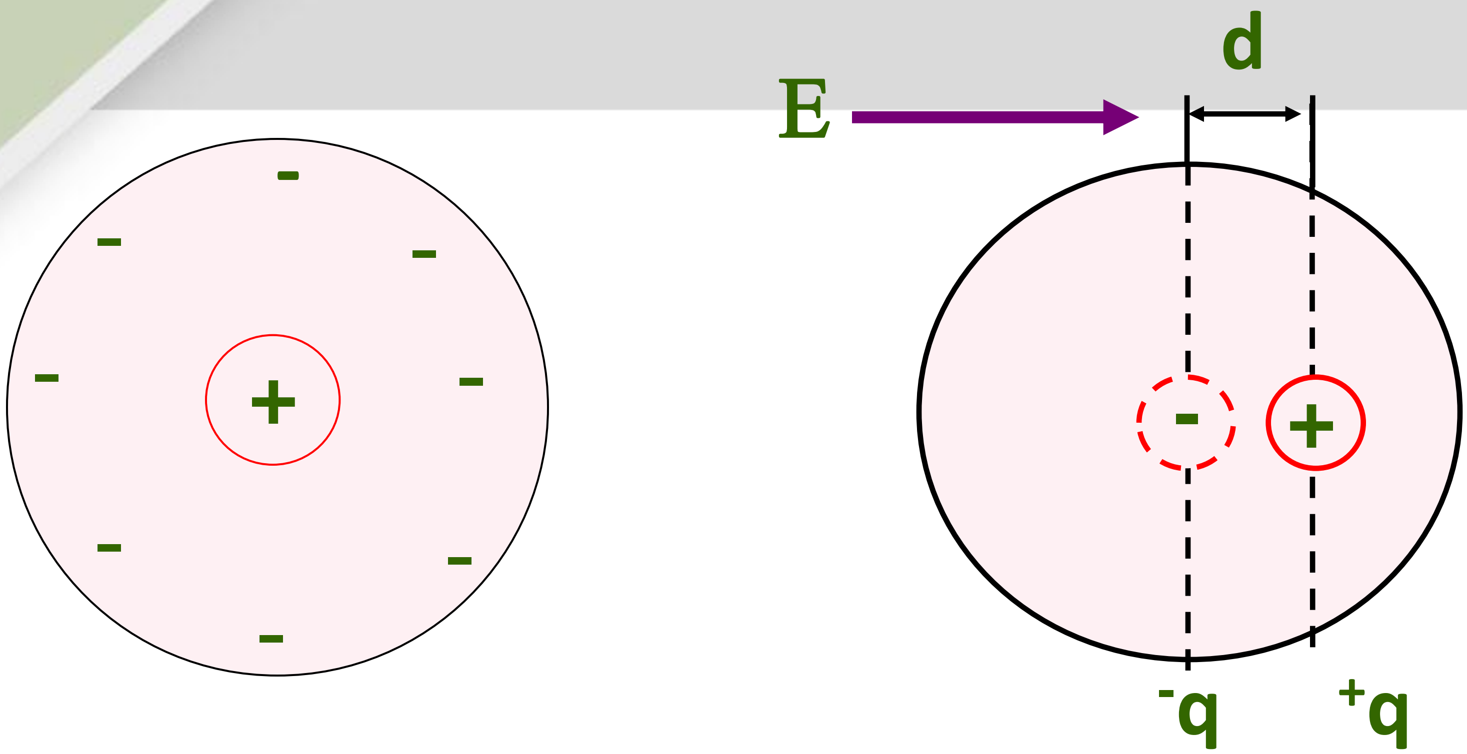
Polarization



Polarization



Polarization



The separation of negative and positive charges and the resulting induced dipole moment are also termed polarization

Polarization

The volume-independent polarization "P" of the material is given as:

$$\underline{P} = \frac{\sum \overleftarrow{\mu}}{V} = N\mu_{av}$$

where:

V is the volume

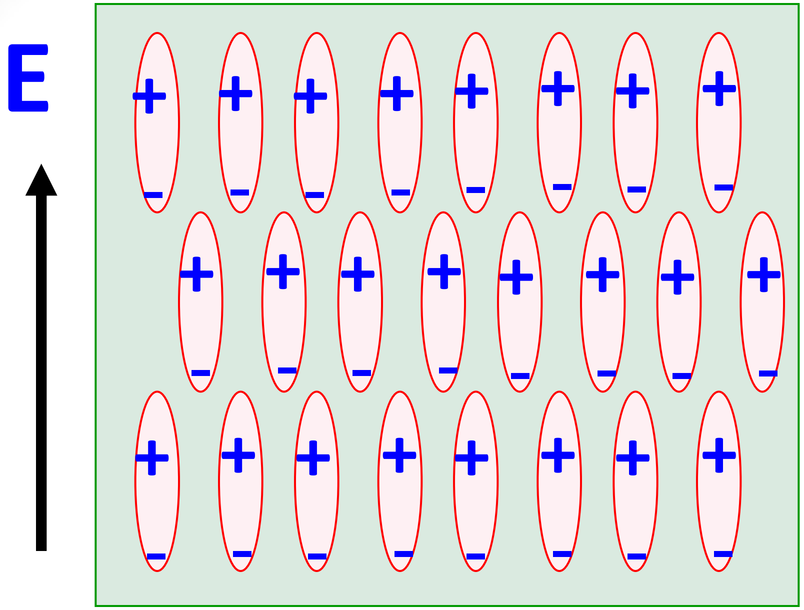
N is the number of molecules per unit volume

μ_{av} is the average dipole moment per molecule

The physical dimension of the polarization is C/m^2 with same dimension of an "area charge"

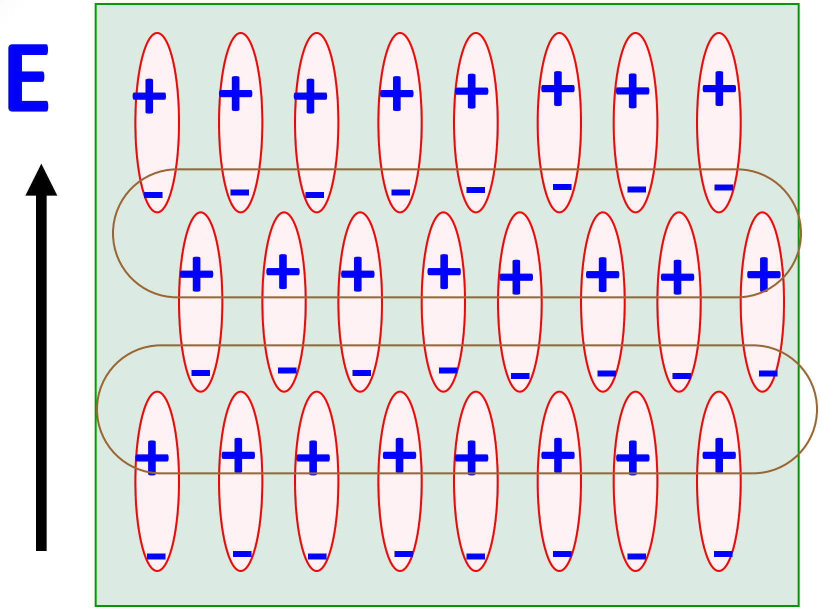
Polarization

$$\underline{P} = \frac{^{+}q}{A}$$ = surface polarization charge density



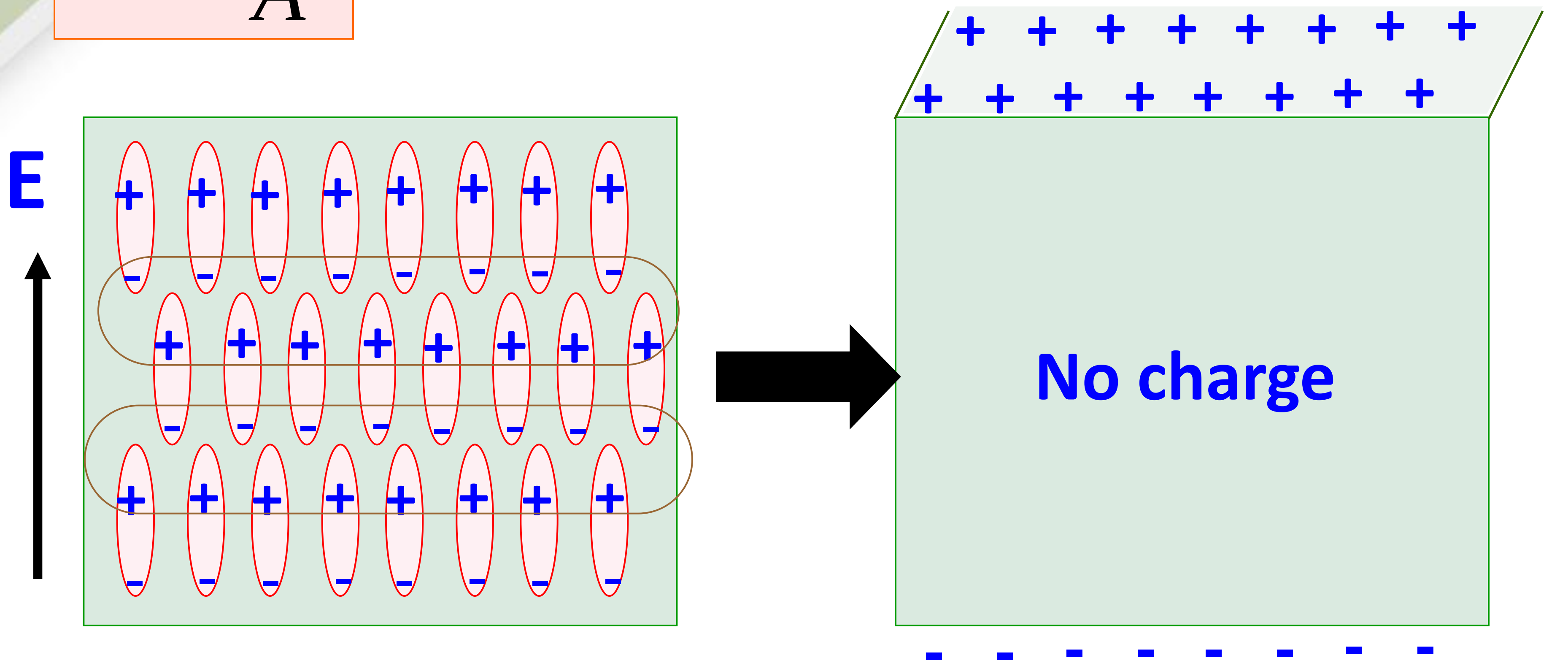
Polarization

$$\underline{P} = \frac{{}^{+}q}{A}$$ = surface polarization charge density



Polarization

$$\underline{P} = \frac{{}^{+}q}{A}$$ = surface polarization charge density



Polarization

The relation between the electrical field causing the polarization and the amount of polarization produced has a linear nature as follows

$$\underline{P} = \varepsilon_0 \ \chi \ \underline{E} = N \alpha \ \underline{E} \qquad\qquad \chi = N \alpha / \varepsilon_0$$

where: ε_0 is the permittivity constant of vacuum

$= 8.85*10^{-12}$ Farads/meter (F/m)

χ is the dielectric susceptibility

α is a coefficient called polarizability

Polarization

An approximate relation between α and ε_r is given as:

$$\boxed{\varepsilon_r = 1 + \chi = 1 + \frac{N\alpha}{\varepsilon_0}}$$

This relation assumes that the field is uniform within the dielectric and hence, the field acting on an individual atom or molecule has the same magnitude as the applied field

Polarization

The actual field acting on molecules differs from point to point

$$\boxed{\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N \cdot \alpha}{3 \cdot \varepsilon_0}}$$

This relation is known as the **Clausius-Mossotti** equation and it assumes different field at each point within the dielectric